A Team-Based Learning Activity for Evaluating a STEM-related Course

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Abstract

Active learning is an education approach where the classical dynamics between teachers and students are swapped around, thus the latter play a more active role, whereas the former play a facilitator role. In this paper, a team-based learning activity related to STEM education is presented, where two-member groups had to first carry out an activity, and then they had to present the results in a pitch presentation to the rest of classmates, which in turn had to evaluate it on a peer review basis. This evaluation process had to be carried out by means of a hand-crafted construct, whose items were previously validated by a panel of experts in the field. The results achieved are considered as successful because average marks obtained were near to the top marks, whereas such results showed internal consistency according to Cronbach's alpha coefficient of reliability and the correlation coefficients calculated. Additionally, the level of engagement of the students while undertaking the activity was measured by means of the ISA engagement construct, whose results confirmed a high level of engagement.

1. Introduction

Active learning could be defined as a student-centric approach for building up knowledge centered on activities and strategies in order to achieve higher-order thinking [1]. This way, both teachers and learners are allowed to interact and get more engaged when it comes to encouraging discussion and critical thinking, along with advanced reasoning skills [2]. In this sense, it has been reported that this alternative approach leads to greater achievements, not only when it comes to student learning, but also in generic working life skills, as well as in competence development [3].

Active learning could be put in place by means of a range of alternative teaching methods, such as educational escape rooms [4], project-based learning [5], or team-based learning [6] in order to enhance student engagement and instructional efficacy [7]. Focusing on the latter, it addresses the importance of concept learning and problem solving [8], as it requires to build understanding by acquiring necessary concepts and knowledge prior to be confronted with real-life problems to be solved [9].

Team-based learning (TBL) approach may be seen as an active, structured form of learning for small groups, which might be extrapolated to large classes [10]. It has been reported to be successfully deployed in the STEM field, such as in medical education [11], science education [12] or engineering education [13], as well as in such as education in social science [14], law [15], or humanities [16].

In this paper, we propose a team-based learning activity for the evaluation of a STEM course, where students are divided into small groups in order to undertake a set of specifications so as to apply the necessary configurations to meet the requirements in a scenario with a network of computer servers.

The rest of the paper is organized as follows: first, Section 2 describes the related work, next, Section 3 introduces the methodology used, in turn, Section 4 presents the results obtained, then, Section 5 exposes the discussion about the results, and eventually, Section 6 draws the final conclusions.

2. Related work

The core point of Team-based learning is group work in order to improve students' ability to apply course content, where the vast majority of class time is devoted to group work. This way, the target of this approach could be summarized in improving learning, as well as promoting the development of self-managed learning teams [17]. In other words, the students' learning is boosted with team-related actions, such as collective decision-making, team cohesion, team communication, and leadership [18].

Team-based learning facilitates and stimulates a cooperative and collaborative instructional strategy in order to delve into knowledge development [19]. On the other hand, team-based learning has been reported to deliver positive results when it comes to students' satisfaction and students' engagement, although results related to knowledge acquisition and retention are somewhat contradictory [20].

Furthermore, online tuition could also benefit of a team-based learning approach. In this sense, Burton et al. presented a systematic review of such an approach, where they obtain similar outcomes regarding face-to-face and online delivery modes,

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even though the latter presents far less instances in the literature [21].

Additionally, there is some confusion around regarding the difference between problem-based learning and team-based learning. Koritakova et al. presented a comparison study where both active learning approaches were found to be well-received by learners, although teachers labeled team-based learning as more demanding when it comes to room set-up, as well as teaching staff coordination [22].

Focusing on its implementation in large enrollment environments, Kibble et al. highlighted some key elements to ensure a successful deployment, such as team formation, readiness assurance process, instant feedback, problem sequencing, establishment of an incentive strategy, and peer review [23]. Likewise, Liu et al. focused on applying this approach in large classes, concluding that better learning outcomes are achieved with a low values of standard deviation [24].

Besides, Jeno et al. looked into the motivational effects on implementing a team-based learning strategy, which resulted in a significant increase in intrinsic motivation, identified regulation, perceived competence, as well as perceived autonomy [25]. Similarly, Swanson et al. concluded that a team-based learning strategy provides deeper understanding of the content and prepare students more effectively for assessments [26].

Also, Zulkifli et al. found that a team-based learning approach encourages learners to work more seriously and effectively in teams, whereas soft skills such as communication ability and self-confidence are enhanced [27]. In summary, as Koh et al. stated, team-based learning could be seen as a student-centered learning strategy, but instructor led, whose approach is highly structured, which is composed of a sequence of activities with the aim of mastering the course concepts, whilst making students accountable for their own preparation and collaboration with their teammates [28].

3. Methods

To start with, we ran a seminar on server configuration and security at a Higher Education Institution in Spain. This was the first edition of such a seminar, and it was held in the first semester of the current academic year, namely 2023-2024. Basically, it was devoted to establishing the fundamentals of server administration in both Windows and Linux.

The evaluation was conceived as a team-based learning activity, where groups of 2 members had to team up in order to accomplish a set of specifications given in advance. As there were 30 participants in the seminar, then 15 teams were formed. Specifically, each team had to build up a scenario composed of a bunch of servers, running either Windows or Linux, such that they had to be properly configured and secured according to a specification set provided to each team in order for servers to be accessible from remote networks in a secure manner.

Hence, each team had to configure the given scenario, and afterwards, they had to make a pitch presentation of around 5 minutes in order to explain it to the other classmates in a special session to hold all presentations. In those presentations, one team member had to present the configurations for the servers in both Windows and Linux, whereas the other one had to run some instances within such a scenario and expose the results. Moreover, right after each pitch presentation, all students had to fill in a construct to rate it, where a set of questions were to be ranked in a 5-point Likert-type scale. This way, each team was assessed on a peer review basis.

This construct for students to evaluate their peers' presentations was hand-crafted by the course teachers, where a series of items were selected, and in turn, those items were validated by a panel of experts in the field. Therefore, those items were included in two different constructs, as one was geared to the validation by a panel of experts, and the other one was geared to evaluate the different teams' presentation by the whole set of students within the classroom.

At the end of the session devoted to deliver the teams' presentation, a third construct was presented to the students in order for them to assess the level of engagement during the team-based learning activity. The construct used in this case was a standard survey called ISA engagement scale, which allows to measure the level of engagement according to three different dimensions, such as intellectual one, social one, and effective one.

In summary, three different constructs were used in order to evaluate this team-based learning activity. The first one was aimed at a panel of experts in order to validate the items of a brand-new construct. Then, the second one was aimed at students in order to evaluate the presentations delivered for each team with the construct previously validated by the panel of experts. And eventually, the third one was also aimed at students in order to assess the level of engagement experienced when undertaking the team-based learning activity.

4. Results

Prior to the session were the presentations were held, it was designed a construct with 6 questions or items, divided into 2 categories, in order for students to rate the different presentations carried out, as exhibited in Table 1. Such a construct was built up from scratch, as this was the first edition of the seminar, hence the construct had to be validated by a panel of experts. Therefore, 5 experts were consulted on each item from two different perspectives, such as the construction of each item and its clarity. A

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specific construct was built up for this purposes, where each of the items were to be ranked in a 4-point Likert-type scale, such that 1 meant fully disagree, 2 meant disagree, 3 meant agree, and 4 meant fully agree. Furthermore, construction and clarity of the items were considered as the dimensions of this construct.

Table 1. Items in the peer-review construct for validation by the panel of experts

Categories	ID	Item
Configuration	Q1	Windows configuration
	Q2	Linux configuration
	Q3	Configuration explanation
Communication	Q4	Functionality
	Q5	Execution
	Q6	Communication skills

Table 2 exposes the average values obtained for each item in each dimension, considering all judges, which leads to calculate the overall average for each dimension, along with the average for the whole construct, and eventually, the Aiken's V test.

Table 2. Aiken's V test of the construct for validation

	Construction	Clarity
AVG Q1	4.0	4.0
AVG Q2	4.0	4.0
AVG Q3	3.4	3.6
AVG Q4	3.6	3.6
AVG Q5	4.0	4.0
AVG Q6	4.0	4.0
AVG for each DIMENSION	3.83	3.87
AVG for whole CONSTRUCT	3.85	
AIKEN'S V TEST	0.95	

The value obtained in the Aiken's V test was greater than the common benchmarks used in the literature, such as the cutoff mark of 0.87 proposed by Aiken [29], the 0.70 suggested by Charter [30], or the 0.50 established by Cicchetti [31]. Hence, even taking the toughest cutoff mark, the value obtained herein is higher, so the construct is considered as validated.

Afterwards, in the session dedicated to deliver the pitch presentations, all students had to rank each presentation according to the items quoted above with a 5-point Likert-type scale, where 1 meant fully disagree, 2 meant disagree, 3 meant neither agree nor disagree, 4 meant agree, and 5 meant fully agree. However, the dimensions considered in this construct for peer-review assessment were the categories established in the construct for judge validation, such as configuration and communication.

Table 3 exhibits the most usual centralization and dispersion statistics of the results obtained [32], which are aggregated by dimensions and overall.

Table 3. Centralization and dispersion statistics of the results, grouped by dimensions and overall

Statistics	Configuration	Commun.	Overall
Average	4.61	4.35	4.51
Mode	5	5	5
25^{th} Percentile	4	4	4
Median	5	4	4
75^{th} Percentile	5	5	5
Variance	0.29	0.43	0.36
Standard Deviation	0.53	0.66	0.60
Coefficient ofVariation	0.12	0.15	0.13

Additionally, the reliability of those results was found out through the Cronbach's alpha [33]. Table 4 presents such a value for each dimension and overall.

Table 4. Cronbach's alpha for the results obtained, grouped by dimensions and overall

Configuration	Communication	Overall
0.87	0.74	0.71

The reliability of the results also gives information about their internal consistency and their correlation between dimensions [34]. The latter could also be measured by applying Pearson's correlation coefficient, and with its Spearman's rank counterpart as well, between the results corresponding to each dimension, as is shown in Table 5.

Table 5. Correlation coefficients between the results obtained in both dimensions

Pearson's correlation coefficient	0.71
Spearman's rank correlation coefficient	0.69

Eventually, after all presentations were done, a final construct was passed on to all students in order to measure their level of engagement. It is to be noted that engagement in active learning is modeled as the product of motivation and experience perceived [35], hence engagement is a crucial factor leading to improving performance. There are different scales to measure engagement, even though

Table 6. The ISA engagement scale

Dimensions	Items
Intellectual Engagement	I focus hard on my work.
	I concentrate on my work.
	I pay a lot of attention to my work.
Social Engagement	I share the same work values as my colleagues.
	I share the same work goals as my colleagues.
	I share the same work attitudes as my colleagues.
Affective Engagement	I feel positive about my work.
	I feel energetic about my work.
	I am enthusiastic in my work.

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the ISA engagement scale was chosen herein [36]. It is composed of 9 standard questions, equally distributed into 3 dimensions, such as intellectual, social, and effective, as seen in Table 6.

Each of these items were rated in a 7-point Likert-type scale, where 1 meant fully disagree, 2 meant disagree, 3 meant partially disagree, 4 meant neither agree nor disagree, 5 meant partially agree, 6 meant agree, and 7 meant fully agree. The goal in this construct is to get an average value of at least 6 in each dimension, thus leading to an overall value higher than 6 [37], which is the value given to agree. Table 7 shows the main descriptive statistics attained out of the results from the construct to measure the level of engagement [38].

Table 7. Descriptive statistics of the outcome achieved, organized by dimensions and overall

Statistics	Intell.	Soc.	Affect.	Overall
Average	6.48	6.57	6.62	6.55
Mode	7	7	7	7
25th Percentile	6	6	6	6
Median	7	7	7	7
75th Percentile	7	7	7	7
Variance	0.57	0.34	0.22	0.40
Standard Deviation	0.75	0.58	0.47	0.63
Coefficient ofVariation	0.12	0.09	0.07	0.10

Furthermore, the reliability of these results got calculated through the Cronbach's alpha, which assesses the internal consistency of data within each dimension and overall, as well as the degree of correlation among dimensions, as shown in Table 8.

Table 8. Cronbach's alpha for the results attained for engagement level, set up by dimensions and overall

Intellectual	Social	Affective	Overall
0.88	0.82	0.91	0.77

5. Discussion

To begin with, three constructs were used to evaluate the team-based learning activity proposed. First of all, a construct was design with six items, equally distributed into two categories, namely configuration and communication. This first construct was aimed at a panel of five experts in order for them to rate each item from two different points of view, namely its construction and its clarity, which were referred to as the dimensions of this construct. The ratings were done through 4-point Likert-type scales, and the overall average was used to calculate the value of the Aiken's V test in order to measure the validity of this construct composed of six items.

The average for the construction domain was 3.83 out of 4, whereas the average for the clarity domain was 3.87 out of 4, thus yielding an overall average of 3.85 out of 4, which could be considered as a quite high value, and the reason may well be that the items were defined in a very straightforward manner. In fact, all judges totally agreed with four of the items, which were considered to be absolutely necessary in the instrument, whereas there were slight differences regarding the remaining two items. Anyway, the overall average led to a value for the Aiken's V test of 0.95, which is clearly higher than the usual benchmarks set in the literature. Hence, this construct with six items got validated.

It is to be considered that there are different agreement benchmarks established in the literature, such as 0.87 proposed by Aiken, 0.70 proposed by Charter, or 0.50 proposed by Cicchetti. Considering those common values, it could be stated that the lower the benchmark, the looser the agreement among judges is permitted, and analogously, the higher the benchmark, the tighter the agreement among judges is allowed. This way, a greater level of discrepancy among judges is possible if the Cicchetti's cutoff mark is assumed, whereas a moderate level of discrepancy is admitted when the Charter's cutoff mark is taken. On the other hand, the assumption of the Aiken's cutoff mark implies a lower level of discrepancy among judges, which in fact was achieved in the validation of the six items composing the hand-made construct in this case.

Afterwards, those six items were included in a second construct in order for students to rate the team-based learning activities presented by each of the different groups. In this construct, the aforementioned categories in the previous construct were considered as the dimensions in the current instrument, whilst the ratings were done by means of 5-point Likert-type scales.

The aggregated results per dimension were pretty similar, although the configuration dimension presented a slightly higher value for the mean, namely 4,61, and a bit lower value for the standard deviation, namely 0.53, whereas the communication dimension exhibited a slightly lower value for the mean, namely 4.35, and a bit higher value for the standard deviation, namely 0.66. Hence, a slightly lower coefficient of variation was spotted in the first dimension, namely 0.12, than in the second one, namely 0.15. Consequently, the values of those descriptive statistics for the overall results were located between the values related to those dimensions in each of the statistics exposed, namely 4.51 for the mean, 0,60 for the standard deviation, and 0.13 for the coefficient of variation. As a side note, the mode obtained in both dimensions and overall was 5, namely the top score, whereas all the quartiles were worth either 4 or 5, which are the higher marks available. These small differences between dimensions may well be due to the fact that

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STEM students are usually better off at undertaking technical stuff, like configurating devices, than at carrying out soft skills tasks, like communicating to an audience. Anyway, it is to be noted that the average values for each dimensions and overall are well above the agree level, which is 4 in this construct. On the other hand, the coefficient of variation is lower or equal than 0.15 in all cases, which is the boundary of low variability for the data collected, hence it may be said that the results obtained were acceptable.

Furthermore, the reliability of the results acquired was measured through the Cronbach's alpha, which resulted in an overall value of 0.71. This value is higher than 0.7, which is the benchmark for acceptable internal consistency of data, so the results obtained were considered as reliable, as well as having internal consistency overall. Likewise, focusing on the dimensions, the Cronbach's alpha for the configuration dimension was 0.87, whereas it was 0.74 for the communication dimension. The former means that the internal consistency of the first dimension was good, as it got above 0.8, and it got near 0.9, which accounts for excellent. On the other hand, the latter means that of the internal consistency of the second dimension was acceptable, as it was above 0.7.

Additionally, acceptable values of reliability are usually related to a high correlation between the data within the dimensions involved. In order to check this out, the Pearson's correlation coefficient and the Spearman's rank correlation coefficient were calculated, which accounted for values higher than 0.5 in both cases. Hence, there was a high correlation between the results obtained in both dimensions.

After that, the level of engagement was measured with a third construct, namely the ISA engagement scale. This construct is composed of nine standard items, equally distributed into three dimensions, such as intellectual, social, and affective, where the ratings were done through 7-point Likert-type scales.

The aggregated results per dimension were fairly similar, namely a mean of 6,48 and a standard deviation of 0.75 for the intellectual dimension, a mean of 6.57 and a standard deviation of 0.58 for the social dimension, and a mean of 6.62 and a standard deviation of 0.47 for the affective dimension. As a side note, the mode obtained in all three dimensions and overall was 7, namely the top score, whereas all the quartiles were worth either 6 or 7, which are the higher marks available.

Therefore, the intellectual dimension got a slightly lower value for the mean and a bit higher value for the standard deviation, whilst the social dimension got a slightly higher value for the mean and a bit lower value for the standard deviation, while the affective dimension got an even slightly higher value for the mean and an even bit lower value for the standard deviation. Hence, a slightly higher coefficient of variation was found in the first dimension, namely 0.12, a bit lower in the second one, namely 0.09, and even a bit lower in the third one, namely 0.07.

Consequently, the values of those descriptive statistics for the overall results were located pretty close to those of the second dimensions in each of the statistics exposed, as those are located in between the those belonging to the first and the third dimensions. Specifically, the overall mean was 6.55, the standard deviation was 0.63, and the coefficient of variation was 0.10. In addition to it, the difference between the mean value for the intellectual dimension and the other two dimensions are greater than the difference between those dimensions, which seems to point out that students got slightly more engaged socially and affectively than intellectually, whereas it also seems that they got a little bit more engagement affectively than socially.

Besides, the reliability of the data achieved in for the overall construct to measure the level of engagement was done by means of the Cronbach's alpha. This measurement was 0.77, which is considered acceptable for being greater than 0.70. Likewise, it implies an internal consistency of the data collected, as well as a high correlation among dimensions. Moreover, the reliability attained in the intellectual dimension was 0.88, which is considered good for being higher than 0.8, whilst it was 0.82 for the social dimension, which is also seen as good, whereas it was 0.91 in the affective dimension, which is taken as excellent for being higher than 0.9. Additionally, high values of Cronbach's Alpha imply a high level of correlation among datasets.

Eventually, it is to be reminded that this is the first edition of this course, so there are no results from previous academic years to compare with. Anyway, according to the literature, the implementation of activities with an active learning approach usually rises both academic performance and success rate in STEM courses. For instance, it has been reported an increment in the former of around 15% [39], whereas the growth in the latter has been reported to be around 20% [40].

6. Conclusions

In this paper, a team-based learning activity has been exposed for evaluation purposes in a STEM course. Basically, the activity was to be carried out in groups of 2 members, where each group had to undertake a set of specifications regarding a list of configuration and security issues provided for a bunch of servers within a computer network. After that, in a specific evaluation session, each group had to make a pitch presentation, where both team members had to expose what they did and how they did it to the rest of their class mates, who in turn had to evaluate them on peer review basis, according to a

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set of items previously established for this activity.

Three different constructs were used in order to set up the evaluation of this team-based learning activity. The first one was a 4-point Likert-type scale construct, intended for a panel of five experts to judge the six items proposed for this construct according to the construction and the clarity of each item. The average rates attained were used to calculate the Aiken's V test, which yielded a value of 0.95. This value was higher than the usual benchmarks quoted in the literature, such as the 0.87 established by Aiken, the 0.70 taken by Charter, and the 0.50 setup by Cicchetti. Hence, as the value obtained in this case is higher than the most restrictive one, because $0.95 > 0.87$, thus this six-item construct got validated.

Those six items within this first construct were inserted into a second construct, which was a 5-point Likert-type scale instrument, intended for students to evaluate the pitch presentations made by all teams. The statistics on the aggregate rates per dimension and overall indicate a good performance, as they were all well above the agree level, which is stated as 4 in this construct, namely the second greater rate. However, it is to be noted that items related to configuration got slightly higher rates than those related to communication, whereas the coefficient of variation in all cases were lower than 0.15, which indicates low variability of the results in both dimensions and overall.

Furthermore, the reliability of the results obtained was measured through the Cronbach's alpha, which accounted for 0.71 overall, thus yielding an acceptable value for being higher than 0.7, and so were the reliability related to each given dimension.

Those values accounted for the internal consistency of the results obtained, as well as for the high correlation in the results for each dimension. The latter was also corroborated by means of calculating the Pearson's correlation coefficient and the Spearman's rank correlation coefficient between the results belonging to each dimension, which yielded a value higher than 0.5 in both cases, which is considered as the benchmark for high correlation.

After all pitch presentations were delivered, then the level of engagement was measured by means of the ISA engagement scale, which is a specific construct composed of 9 standard items equally distributed among 3 dimensions, namely intellectual, social, and affective. Hence, this third construct was a 7-point Likert-type scale instrument, intended for students to measure their engagement level during the team-based learning activity.

The average values obtained for each dimension were all higher than 6, namely the second highest rate. Specifically, the values attained for each dimension were 6,48 for the intellectual dimension, 6.57 for the social one, and 6.62 for the affective one, thus leading to an overall value of 6.55. All those values were well above the agree level, which is stated as 6 in this construct, thus representing a high level of engagement.

Furthermore, the coefficients of variation for each dimension and overall were all lower than 0.15, hence accounting for low variability in the outcome attained. Additionally, the Cronbach's alpha measured for the whole set of results was 0.77, which accounts for an acceptable reliability of the results for the engagement level for being higher than 0.7, thus standing for their internal consistency and high correlation of such results. Likewise, the values of the Cronbach's alpha referred to each dimension were also higher than 0.7, which also account for a high level of correlation among the dimensions considered.

In summary, the team-based learning activity proposed can be considered as a success because of the academic performance obtained by the students as well as the level of engagement experienced. Therefore, according to those results, it could be stated that the use of team-based learning activities for evaluating this course delivered outstanding results.

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